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**GREEN RIVER FOODWEB:
COLORADO SQUAWFISH NURSERY HABITAT
NEAR OURAY NATIONAL WILDLIFE REFUGE, UTAH**

by

Linden Hamer Alder

Thesis submitted in partial fulfillment
of the requirements for the degree

of

**UNIVERSITY HONORS
WITH DEPARTMENT HONORS**

in

Forest Resources

UTAH STATE UNIVERSITY
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1995

1
2 THE ROLE OF INTRODUCED FISHES IN THE GREEN RIVER:
3 EXOTIC PREDATORS IN NURSERY HABITATS
4 OF THE ENDANGERED COLORADO SQUAWFISH
5

6 KEYWORDS: introduced fish; predictive predation; endangered fish; foodweb
7 dynamics; competition; spatial distribution; Utah; Upper Colorado River; Green
8 River
9

10
11 ABSTRACT
12

13 Effects of fish introductions are relatively well studied in lentic habitats, and apparently range from
14 extremely disruptive to notably benign (Kruegger and May 1991). Though researched less
15 completely, fish introductions may also alter native faunas in lotic habitats. Ptychocheilus lucius,
16 commonly known as the Colorado squawfish (*C. squawfish*), is a fish species endemic to the
17 Colorado river system. The population is currently experiencing dramatically reduced recruitment
18 successes relative to historical rates. Introduced fishes such as channel catfish, smallmouth bass,
19 and green sunfish are prevalent in the Upper Colorado River. The introduced fish presence is
20 increasingly suspected by researchers as a factor limiting *C. squawfish* recruitment (Minckley
21 1991). Direct predation, particularly on Young-Of-the-Year (YOY) and juvenile (2-5 year)
22 squawfish in nursery habitat areas is potentially the most severe factor limiting *C. squawfish*
23 recruitment. Results of cage experiments (Schaugaard, unpub. data) suggest that at least
24 smallmouth bass, small channel catfish and green sunfish consume *C. squawfish*. Given the
25 domination (both in terms of densities and biomass) of the foodweb by introduced fishes, I
26 hypothesize that the overall energy balance in the upper basin system is dramatically altered relative
27 to historic states. Most energy in the system, at all levels, now appears to flow through introduced
28 fish.
29

30 As a first step toward testing the predator-impact hypothesis, a foodweb model, developed from
31 three years of data, is presented. These data estimate previously unknown quantitative assessments
32 of the Green River fish community, including prey body length/predator gape size relationships,
33 predator stomach contents, and relative densities of introduced predators in a 60 mile flatwater
34 reach of the Green River which has been identified as key nursery habitat for YOY *C. squawfish*

1 (Schmidt pers. comm.). Finally, I develop a native fish predation risk model, based on these data,
2 to determine to the extent that direct predation alone could contribute to the population trends
3 currently exhibited by *C. squawfish*.
4
5

INTRODUCTION

Aquatic ecologists studying stream biota are currently engaged in a disagreement about factors controlling population and community dynamics. The "abiotic" group argues for the predominance of abiotic factors such as flow fluctuations and habitat availability (Flecker and Allan 1984, Diamond and Reice 1985, Gillam and Fraser 1989, Thorp and Cothran 1984) while "biotic" theorists suggest that interactions (such as intraspecific competition or the abundance of primary productivity) between living organisms are the dominant forces structuring stream community dynamics (Gillam et al. 1989, Crowder and Cooper 1982, Power et al. 1985, Peckarsky 1980). More recently, researchers have proposed that only a combination of both biotic and abiotic factors provide reasonable explanation of stream biota control (Soluk and Collins 1988, Dudgeon 1991, Brusven et. al 1990, Power et al 1988).

Among the factors important to "biotic" proponents, the effect of introduced fishes on native fishes is prevalent (Minckley 1991, Courtney and Stauffer 1984). These potential impacts can be classified as either ecological or genetic. Ecological impacts include processes or mechanisms such as competition, predation, and physical habitat modification (Taylor et al. 1984, Moyle et al. 1986). Genetic effects involve processes which change the gene pools of populations and species (e.g. hybridization). Theoretically, ecological and genetic effects may cause native species to (1) be eliminated, (2) have changes in growth and survival, (3) be genetically changed, (4) alter community structure, (5) exhibit combinations of the above, or (6) exhibit no detectable changes (Moyle 1986, Krueger and May 1991). While the effects listed above result mainly from research in lentic habitats, the impacts of introduced fish on native fish faunas in stream and river contexts are less well known.

The issue of introduced fish impacts is particularly important in the Colorado river system where four native species are currently listed as endangered by the U.S. Fish and Wildlife Service (Miller and Hubert 1990). Declining numbers of *C. squawfish* are well documented (Miller 1961, Minckley 1965, 1973, 1985, Minckley and Deacon 1968, Crowl pers. comm., Valdez 1989). Recent declines in observed squawfish led the U.S. Fish and Wildlife

1 Service (FWS) to include the fish on the Endangered Species List on March 11, 1967, and again
2 under the amended Endangered Species Act on January 4, 1974 (U.S. Fish and Wildlife Service
3 1991).

4
5 Researchers have forwarded many hypotheses regarding the decline of native fish
6 numbers (Fradkin 1981, Reisner 1986, Carothers and Brown 1991), such as flow
7 regulation by dams resulting in changed biomass and energy flows through the
8 system, reduced spawning success due to blocked migratory routes and/or spawning
9 habitat (Minckley 1991, Carothers and Brown 1991, Tyus and McAda 1984, Tyus
10 1986), reduced flow and habitat availability resulting from water withdrawals
11 (Minckley 1991) and depressed summer flow temperatures (Minckley 1991). Recently, discussion
12 of potential introduced fish impacts has gained more widespread exposure (Minckley 1991,
13 Carothers and Brown 1991, Crowl, pers. comm.).

14
15 The following research attempts to test the assumption that a predator risk model can successfully
16 estimate the extent of introduced fish predation on native fish populations. Such estimates may
17 provide important data for river managers who attempt to balance the many values which the Green
18 River is expected to provide including native fish habitat, recreational angling and hydropower. A
19 reliable model, correctly applied, could also provide important estimates of introduced fish
20 predation in other regions of the Colorado River basin as well as other watersheds.

21 22 Colorado Squawfish life history overview

23
24 The Colorado squawfish is the largest North American member of the minnow
25 family Cyprinidae (Miller 1961). It is the largest of four living species of the genus
26 Ptychocheilus, and as a voracious predator, was once the top carnivore of the
27 Colorado River system (Miller 1961, USFWS 1991). Historical observations of the C. squawfish
28 by early explorers and residents characterized the species as widespread
29 through the Colorado River system, robust, often very large (up to 36 kg and 1.8
30 meters), and tasty for the palate (Minckley 1973; Behnke and Benson 1983, USFWS 1991).

1 Researchers believe that the Colorado squawfish adapted to environments
2 characterized by swift water, regular flow fluctuations resulting from seasonal effects
3 and relatively dramatic climactic fluctuations. Recently, C. squawfish have been
4 observed participating in spawning migration runs over distances of up to 400 km. (Tyus 1985,
5 Haynes and Muth 1985), which may be shorter than pre-dam migrations (Crowl pers. comm.).
6 Adult squawfish apparently make spawning runs when river discharge begins to descend after peak
7 spring flows (Uyeno and Miller 1965, G. Smith 1975 & 1981, M. Smith 1981, Tyus 1986).
8 Gravel spawning bars are found at the furthest upstream point of observed migrations (Miller and
9 Hubert, 1990).

10
11 Life history requirements, population status, habitat preferences, interspecific and
12 intraspecific competition, and reintroduction success rates are not fully understood (Miller and
13 Hubert 1990, USFWS 1991, Crowl pers. comm. 1994, Stanford 1993).

14
15 Researchers have observed an annual migration of as many as hundreds of
16 thousands of larval squawfish from the spawning bars in the Yampa River (Fig. 1)
17 into the Green River (Haynes et al. 1984, Miller et al. 1982). Migration appears to be an important
18 part of the fish's life cycle (Tyus and Haines 1991). During this yearly migration, however,
19 researchers have observed an annual mid-summer disappearance of thousands of larval squawfish
20 along mainstem Green River stretches (Schaugaard and Crowl pers. comm. 1994).

21 22 Theoretical basis

23
24 The purpose of the following research is to consider the following null hypotheses:

- 25
26 1- Direct consumption of native fish by nonnatives alone cannot account for
27 reduced C. squawfish survival and recruitment rates observed during their first year of life.
28
- 29 2- Correlations between observed predator gape and prey height cannot be useful in
30 predicting the relative risk of C. squawfish loss to predation by introduced fishes.

Resources for the development of a predictive predation model in the Green River are limited, particularly if one is in search of observed diets of introduced fishes. Sigler and Sigler (1987) and Miller and Hubert (1990) provide baseline data concerning such diets. Much of the published research focuses on abiotic factors influencing recruitment, particularly habitat availability (but see Minckley et al. 1991).

Very few sources exist to develop an understanding of the larger foodweb view which includes fish densities (both overall and by species), spatial distributions and trends, predator/prey size relationships, and energy flow through the system. As a result, researchers and managers operate with only the roughest of estimates concerning such data.

To develop a reliable predation model in the Green River, field research must be designed to address a number of key questions. First, what is the composition, in sheer numbers, species diversity, and size structure of introduced fish populations? Second, when based on fish predator size class, what sizes of prey can possibly be eaten? Third, based on stomach analysis, what are introduced fish actually eating, both in terms of sizes and species? Finally, based on the first three, what theoretical impacts may introduced fish, at observed densities and size distributions, have upon native fish populations?

METHODS AND MATERIALS

Field study site

Colorado squawfish nursery habitats are characteristically low gradient, relatively complex stretches with numerous permanent, semi-permanent and ephemeral backwater structures (Schmidt pers. comm.). Such habitats occur downstream of known spawning sites. YOY C. squawfish congregate in these habitats following emergence and passive transport through higher elevation, typically higher gradient reaches. When C. squawfish YOY appear in the nursery habitat reported herein, their average total length is 25 mm (Schaugaard unpub. data 1993,

1 1994). As the YOY progress through the summer, they exhibit ontogenetic feeding behaviors from
2 planktivores to piscivores (Miller and Hubert 1990, Schaugaard unpub. data, USFWS 1991,
3 Minckley 1991, Vanicek and Kramer 1969).
4

5 One of the three remaining C. squawfish nursery habitats in the Colorado River system occurs
6 between river mile (RM) 200 and 305 (Green and Colorado River confluence = mile 0). It is from
7 data gathered in this low-gradient (less than 0.003 meters/meter) 60-river mile stretch of the Green
8 River that the following predation model is developed (Schmidt pers. comm).
9

10 Field sampling techniques

11

12 Beginning after spring runoff subsided¹, field sampling occurred during the last week of four
13 consecutive summer months, June through September, 1994. Scant summer storms provided a
14 drier-than-average summer season.
15

16 A Coffelt VVP-15 electroshocking unit provided regulation of electricity generated
17 by an on-board Honda 20 horsepower generator. A 20' aluminum research skiff, powered by a 40
18 horsepower outboard motor, was used as the fish collection vehicle. Wires connected the
19 generator to two metal spheres which were wired into retractable fiberglass poles. Always
20 submerged at least half way while delivering electricity, each spheres' diameter covered (roughly)
21 30 cm. When extended, the 6 cm. (diameter) poles reached 2.5 meters ahead of the boat.
22

23 Electrical current was controlled by a toggle switch on the Coffelt device (operated by the boat
24 handler) and a foot pedal operated by the fish collecting technician standing on a raised bow
25 platform. Electricity flowed into the river both switches were "on." Variable control knobs on the
26 Coffelt device were set at "DC output" and "DC on," maintained pulse width at 90-100%, pulses
27 per second at 120-150, volts at 300 (+/- 50), and amperes 10 (+/- 3).

¹ Though the reach in which research was conducted occurs downstream of Flaming Gorge Dam, releases were managed, based upon a Bureau of Reclamation experiment, to reflect spring runoff entering Flaming Gorge Reservoir.

Two wood-handled nets, both with hoop diameters near 0.75 meters, were utilized during each monthly collecting trip. Nets included a 20 mm nylon mesh net and one collapsable metal net with an effective mesh of 50 mm. Their lengths, ranging from 1.9 to 2.2 meters, allowed technicians to collect fish across effective shocking width, which was assumed to be 3.5 meters. Consistent turbidity clearly limited the effective collection area.

Sampling units

For practical purposes, the 105 river mile reach of suspected *C. squawfish* nursery habitat is divided into three roughly equal stretches. These are known as *locations*.

Furthest upstream, the "Jensen" location begins at the Highway 40 bridge in Jensen, Utah (Fig. 1). Measured upstream from the Green's confluence with the Colorado River (as all locations herein are identified), this bridge stands near RM 300. Due to physical constraints, roughly 6 miles of this location were sampled. Ashley Creek, a small tributary, ephemeral backwater structures, and numerous bank stabilization structures highlight this reach.

The Ouray National Wildlife Refuge (known as "refuge") occurs roughly between RM 240 and 230, downstream from Jensen. Due to physical constraints, sampling in this location did not extend beyond refuge borders. Large, semi-permanent backwaters and a pair of perennial secondary channels characterize this reach.

Below the refuge, both the sizable Duchesne and White rivers join the Green River in the location known as "Duchesne." Like the two upstream locations, this stretch has relatively low gradients and many backwaters. This location lies roughly between RM 230 and RM 218.

Beginning in late-June of 1995, YOY squawfish appeared throughout the three locations. Technicians observed the fish in sein hauls of backwater habitats (Schaugaard unpub. data). While not numerous, *C. squawfish* appearance provided certainty regarding nursery habitat utilization.

1 Field sampling techniques

2
3 Within each of the three locations, ten *sites* were selected for sampling within each reach. A
4 typical site shocking/collection began when technicians selected the site (based on ease of
5 collecting, lack of previous shocking, habitat variability, etc.) and prepared the generator, nets and
6 live well. When electricity was applied to the river, fish were collected. Once finished, a "hip-
7 chain" was used to measure linear shock length.

8
9 Site notations, including date, time of day, riverbank (river right or left), shock length, habitat
10 descriptions, site and location name (e.g. Jensen 7) were then recorded. All native fish were
11 weighed, measured, and released, while a second technician used alcohol to preserve fish in bottles
12 and bags. Each bottle or bag received an identification tag.

13
14 Technicians attempted to sample both river banks roughly opposite each other. Two concurrent
15 sites (e.g. "Refuge 3 & 4") represent both banks at roughly the same river mile.

16
17 Laboratory analysis

18
19 During the above-mentioned collecting trips, more than 1,500 fish made their way into bags and
20 bottles filled with 70% Ethyl alcohol. Once in the laboratory, two general types of information were
21 gathered from the collection. First, the entire collection was analyzed by assembling information
22 regarding species, total and fork length, gape (estimated by inserting a glass rod into mouth and
23 throat of fish), wet weight, and number of fish (by species and total) per shocking site

24
25 Second, stomach content analyses were performed on all introduced fish (minus a subsample of
26 sand and red shiners). Stomach analysis included estimated percentage of stomach content (by
27 type, e.g. plant, fish, detritus, etc.), estimated stomach fullness (percent), stomach wet weight, and
28 fish prey length (when present in stomachs).

STATISTICAL ANALYSIS

All data were collated using Quattro Pro for Windows computer spreadsheet applications to manage fish density and stomach content data. All statistical tests were constructed with the SAS statistical package.

Step-wise predation risk modelling

Data collected from the study site over three summer seasons provides reliable basis for three predation risk models. For the sake of statistical simplicity, *predator populations in these models were assigned to 50 mm size classes* (50-100 mm, 100-150 mm, etc). These size classes become very important in models described below. Fish species collected in the Green River were considered either prey or predator based upon body size (Sigler and Sigler 1987).

The ultimate goal of regressions presented below is simple: estimate actual predation risk (R) for prey of given sizes in the presence of predators of given sizes. This estimate cannot be reliably determined from direct observations, so links must be made between observed and logical characteristics of predator/prey interactions.

Pearre, (1986), argues that correlations between predator size and prey size are quantifiable and valuable when developing food web models. Pearre's model is similar to that which appears below. Because actual observations are so difficult to obtain reliably, the preferred theoretical model must link four separate regressions to each other stepwise:

Step 1: regress prey maximum body height against prey TL . Prey depth is assumed to be *the* measurement which limits predation (Pearre 1986).

Step 2: regress predator gape against predator TL. Convenient estimates of predatory influence based on predator size class are provided by this equation.

Step 3: form a standard equation by setting prey size (step 1) equal to predator size (step 2). In the absence of reliable and sufficient actual observations, this equation is the best estimate of predation risk based on both prey and predator size.

Step 3 is performed under the assumption that prey ht. and predator gape represent the maximum size relationship between predators and their prey.

The standard equation (step 3) used to develop risk models is thus:

$$G = b_1 + m_1 (\text{pred TL}) = H = b_2 + m_2 (\text{prey TL}) \quad (\text{eq. 1})$$

where G= predator gape

b_1 = gape regression y-intercept

m_1 = gape regression rate constant

H= prey maximum height

b_2 = prey regression y-intercept

m_2 = prey regression rate constant

which, said more simply...

$$R_x = ([b_1 + m_1 (\text{pred TL})] + m_2) / b_2 \quad (\text{eq. 2})$$

where R_x = risk according to each different model.

Introduced fish densities

Once step 3 is completed, R can be contextualized in the Green River. Observed densities of predators offer further insight into predation risk. The density of introduced predators in C. squawfish nursery habitat can be easily estimated from data on hand (see above).

Effective shock area (ESA) for each site was calculated as the product of river length and shocking width (effective width of the electrical field, estimated at 3.5 m.). Fish density was estimated by dividing the number of fish collected from each site by the ESA.

The following equation was used to determine fish density:

$$D = (l \cdot a) / n \quad (\text{eq. 3})$$

where D = relative fish density

l = length of river shocked (m)

a = surface area (width) constant (3.5 m)

n = number of fish observed

Predator abundance by size class

One step beyond the density issue of introduced predators is that of size class predator abundance. Determining this distribution is simple with the assistance of spreadsheet applications.

RESULTS

The step-wise approach described above can be applied to data collected from the Green River.

When all observed maximum heights of prey fish collected in 1994 are plotted against their respective TL, the following regression (step 1) occurs :

$$\text{prey ht.} = 5.095 + 0.253 (\text{prey TL}). \quad r^2 = 0.8181 \quad (\text{eq. 4})$$

When all observed fish predator gapes are plotted against their respective TL, the following regression (step 2) occurs:

$$\text{pred. gape} = -1.292 + 0.073 (\text{pred TL}). \quad r^2 = 0.7899 \quad (\text{eq. 5})$$

A number of regression models with different series of analysis by species were also performed. The model which included all species was not significantly different than species-specific models. The inclusive model allows the generation of a single, generalized model with prey and predators ordered singly upon body size axes.

Three predation risk models

Model #1 uses the standard equation (eq. 1) to establish a simple relationship between prey size and risk of predation (see Fig. 2). Values included in this equation are derived from regressions base on data collected from the Green River.

$$R_1 = ([-1.29 + 0.07(\text{pred TL})] - 5.1) / 0.25 \quad (\text{eq. 6})$$

Simple direct predation is assumed. Figure 2 depicts relative risk according to model 1, where each curved line represents prey selection for predators in each of the 50 mm. size classes. Each line peaks at the *average* prey size vulnerable to a given predator size class. Niche overlap is assumed to be 0 and theoretical maximum and minimum prey sizes absolute.

Model #2 (fig. 3) estimates risk with two different assumptions: size variation exists among both prey morphology (hence vulnerability) *and* predator gape distribution. To develop the theoretical minimum prey size, one SE is subtracted from prey size parameters determined through equations 1 and 2 and one SE added to predator size parameters. That is, prey height as a function of length is decreased by decreasing both the y-intercept and slope of equation 6. Similarly, predator gape per unit predator length is increased. These adjustments produce the following models:

$$R_{2n} = ([-1.42 + 0.069 (\text{pred TL})] - 6.5) / 0.26 \quad (\text{eq. 7})$$

To determine theoretical maximum prey size, one SE is added to both prey and predator values

$$R_{2x} = ([-1.16 + 0.071(\text{pred TL})] - 3.7) / 0.24 \quad (\text{eq. 8})$$

Each line peaks at average selected prey size, and overlap is expected to occur. Where lines overlap, more than one predator size class is expected to predate upon fish that length.

Model #3 (fig. 4) considers theoretical minimum-size prey selection to be continuous. Minimum prey size per predator size-class was measured empirically from actual fish observed in the stomachs of large (> 100 mm) predators collected during three field seasons. Maximum prey size boundaries are provided in model #1.

The regression of minimum prey size to predator size is:

$$R_{3n} = -6.96 + 0.17 (\text{pred TL}) \quad (\text{eq. 9})$$

Each line peaks at the *average* prey size vulnerable to a given predator size class. Of the three models, this model likely estimates risk most correctly, as Pearre's work (1986) suggests. Large predators eat not only relatively large prey sizes, but also smaller prey sizes which smaller predators eat. Predation risk, therefore, is relatively extreme for smaller individuals on which many predator species and size classes prey.

Green River predator density

Figure 5 exhibits the relative density of introduced predators collected during the 1994 field season. Green sunfish and channel catfish densities are lower than red shiners (note difference of scale for red shiners), but are likely more influential relative to fish predation (Crowl and Schaugard pers. comm.). The red shiner density estimate is deceptively high, since few if any individuals are large enough to predate upon YOY squawfish.

Quantified relative predation risk

In addition to predator densities, understanding the distribution of predators by size class provides insight. Figure 6 describes observed numbers of predators by size class. The following equation provides relative predation risk according to actual observed abundances of each predator size class:

$$R_4 = p(R_{3s}) \quad (\text{eq. 10})$$

where R_4 = relative predation risk estimate

p = number of observed predators

R_{3s} = maximum R determined by model #3 for predator size class "s"

YOY C. squawfish predation in context

Clearly, the risk of predation for a relatively small fish in the studied river reach is great, a fact particularly important in recruitment of YOY C. squawfish. As Osmundson (1987) reported, the body depth/TL regression for C. squawfish is

$$y = 0.280 + 0.144 (x) \quad r^2 = 0.975 \quad (\text{eq. 11}).$$

After their first summers' growth, squawfish tend to average 65 mm in length and 11.9 mm in height. By the end of their second growing season, squawfish average length is 100 mm and height 14.3 mm. (Schaugaard unpub. data, Osmundson 1987). The importance of this fact will be described below.

DISCUSSION

The statistically significant correlations described above are important in relation to stated null

1 hypotheses:

2
3 1- Direct consumption of native fish by introduced predators alone cannot account for
4 reduced C. squawfish survival and recruitment rates, and

5
6 2- Correlations between observed predator gape and prey height cannot be useful in
7 predicting the relative risk of C. squawfish loss to predation by introduced fishes.

8
9 While null hypothesis 1 cannot be completely disproven with available data, model #3 provides a
10 strong theoretical case against it. The case against null hypothesis #2 is arguably very strong based
11 upon the foregoing data and discussion.

12 Model #1 suggests that predators may size-select their prey, and predation risk occurs mainly from
13 specific-sized predators. Model #2 perhaps more correctly estimates predation risk by allowing 1
14 SE for both prey TL and predator gape. Overlapping lines suggest predation risk at higher rates
15 than those estimated by model #1. Likely the most correct of all models, however, is #3 which
16 assumes that predators do not limit their prey selection to the minimum determined by model #2.
17 Prey size selection described by model #3 is similar to that described by Pearre (1986), and is
18 theoretically supported by Meinsinger and Spears (1981). The resulting predation risk occurs not
19 only from one predator but *many* whose selection of prey size varies widely.

20
21 Green River C. squawfish nursery habitat appears to be an extremely unsafe area for any fish
22 smaller than 100 mm, including C. squawfish. For example, model #3 suggests that predation risk
23 for a 25 mm fish occurs from eight of nine predator size classes. Two of those predator size classes
24 exert nearly 100% risk; six others exert risk ranging between 40% and 80%.

25
26 Introduced fish are likely exerting *extreme* influence on the recruitment of YOY squawfish which
27 appear (usually mid-to-late June) in Green River nursery habitat at an average length of 25 mm. As
28 such, the YOY experience an *outstanding* risk of predation.

29
30 Theoretically, these extreme predation risks are experienced by YOY C. squawfish over temporal

spans. Vanicek and Kramer's pioneering work (1969), provides estimates of C. squawfish average sizes through its first 11 years. Seethaler (1978) revisited age class estimations and reported similar averages which deviated only slightly toward a larger average. Observed growth rates of YOY C. squawfish suggest that the average lengths after 12, 24 and 36 months of life are 60, 125 and 180 mm respectively. A typical YOY C. Squawfish is not long enough (60 mm) to avoid predation predicted by model #3 until *16 months* after emergence when it reaches 125 mm.

Estimates of YOY mortality in C. squawfish nursery habitat range from 75% to 90% (Crowl, Burnham). That is, 75% to 90% of each year's YOY population does not live more than 12 months. For a species in dramatic decline, if predation-mediated mortality has increased due to introduced predators, a number of ecological problems occur.

First, where C. squawfish individuals historically lived more than 40 years (Miller and Hubert 1990), increased predation-mediated mortality causes a demographic shift among the population (more adults than juveniles tha. Not enough is known about C. squawfish spawning practices to estimate how long an adult actively and/or successfully spawn. If spawning viability is relatively short or occurs in cycles over many seasons, the decrease in recruited individuals over recent history may lead to even less productive future spawns.

Second, where introduced fish density is higher now than historically, the river's limited biological resources are likely consumed by nonnative populations instead of native species. When an introduced fish species occurs in a system which lacks its evolutionary predator (as in the Green River case with northern pike, channel catfish and smallmouth bass), the introduced fish often experiences a competitive advantage over a native fish (which lives with its evolutionary predators) (Taylor et al. 1984). Therefore, in addition to the predation mentioned above, YOY C. squawfish mortality is most likely increased due to resource competition with nonnative fish.

Continued predation and competition caused by nonnative fish in C. squawfish nursery habitat is likely to expedite the current decline of C. squawfish recruitment in the Green River. For an endangered species whose decline in numbers is well documented, the analysis described above

suggests that deeper consideration of nonnative fish effects occur.

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FIGURE LEGENDS

Fig. 1. Partial map of the Green River basin. Single hatching indicates the known spawning area in the Yampa River. Cross hatching indicates the study site, identified as low-gradient Colorado squawfish nursery habitat.

Fig. 2. Predation risk (vulnerability) based on prey size. Numerical values produced by model #1 appear here. Each curve represents a given 50 mm predator size class, beginning with 100-150 mm. for the furthest left curve and ending with 500-550 mm. to the right. This model suggests that theoretical maximum and minimum prey selections are absolute and do not overlap.

Fig. 3. Predation risk (vulnerability) based on prey size. Numerical values produced by model #2 appear here. Each curve represents a given 50 mm predator size class as in figure 1. This model suggests that theoretical maximum and minimum prey selections are absolute and overlap ± 1 SE.

Fig. 4. Predation risk (vulnerability) based on prey size. Numerical values produced by model #3 appear here. Each curve represents a given 50 mm predator size class, ranging from 100-150 mm. for the furthest left curve to 500-550 mm. on the right. This model suggests that theoretical maximum and minimum prey selections are continuous and that the minimum prey size regression is practically flat.

Fig. 5. Relative abundance of introduced predators by size class collected June-Sept. 1994, Green River, Utah. Note different scale for red shiners on left axis.

Fig. 6. Predator density by predator species per square meter of river surface area sampled, Green River, Utah, June - Sept. 1994.

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Fig. 7. Relative predation risk in context of predator density (by size class) for the Green River, Utah, summer 1994. *Found under Quantified predation risk estimates.*

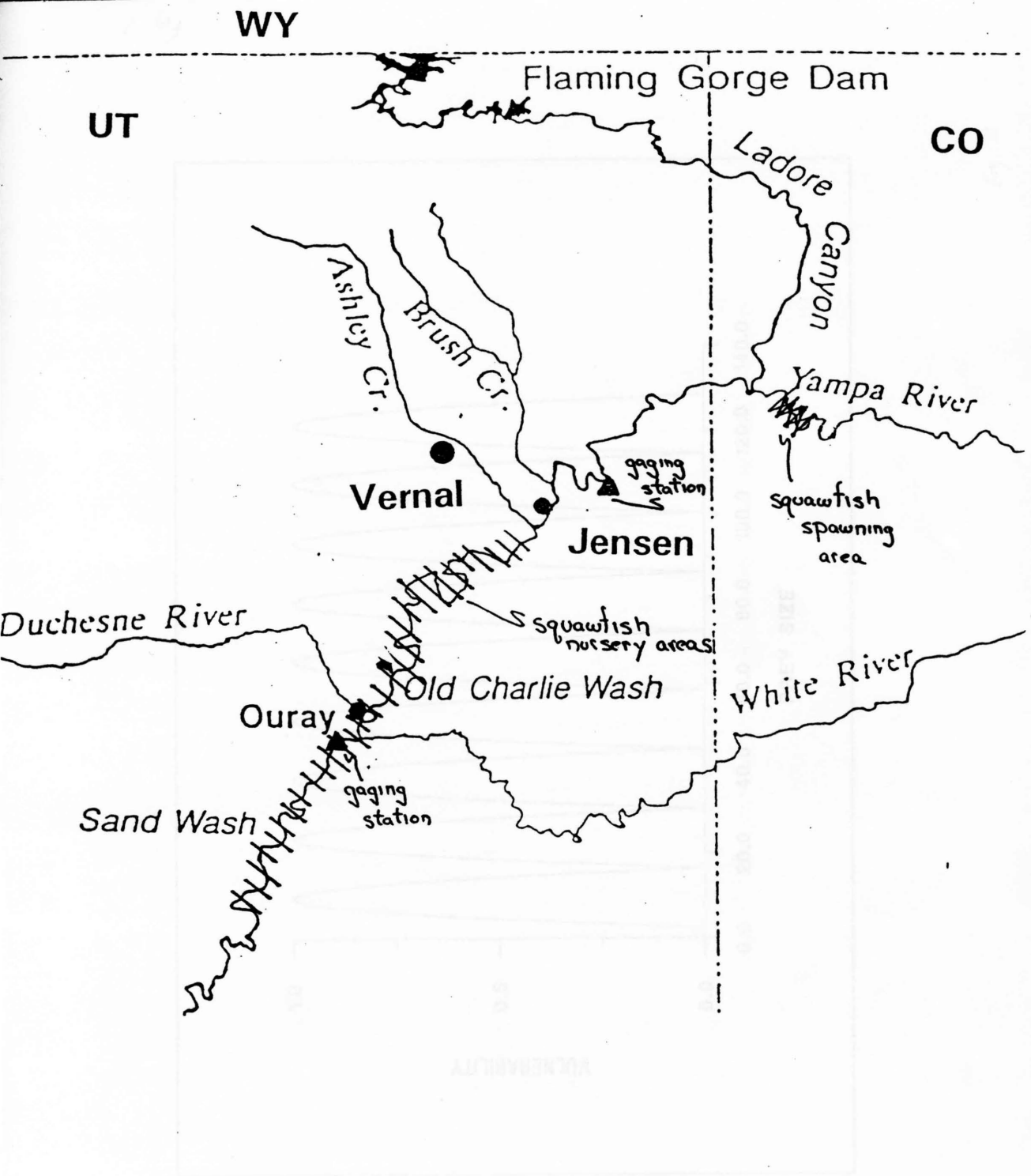


Fig. 1

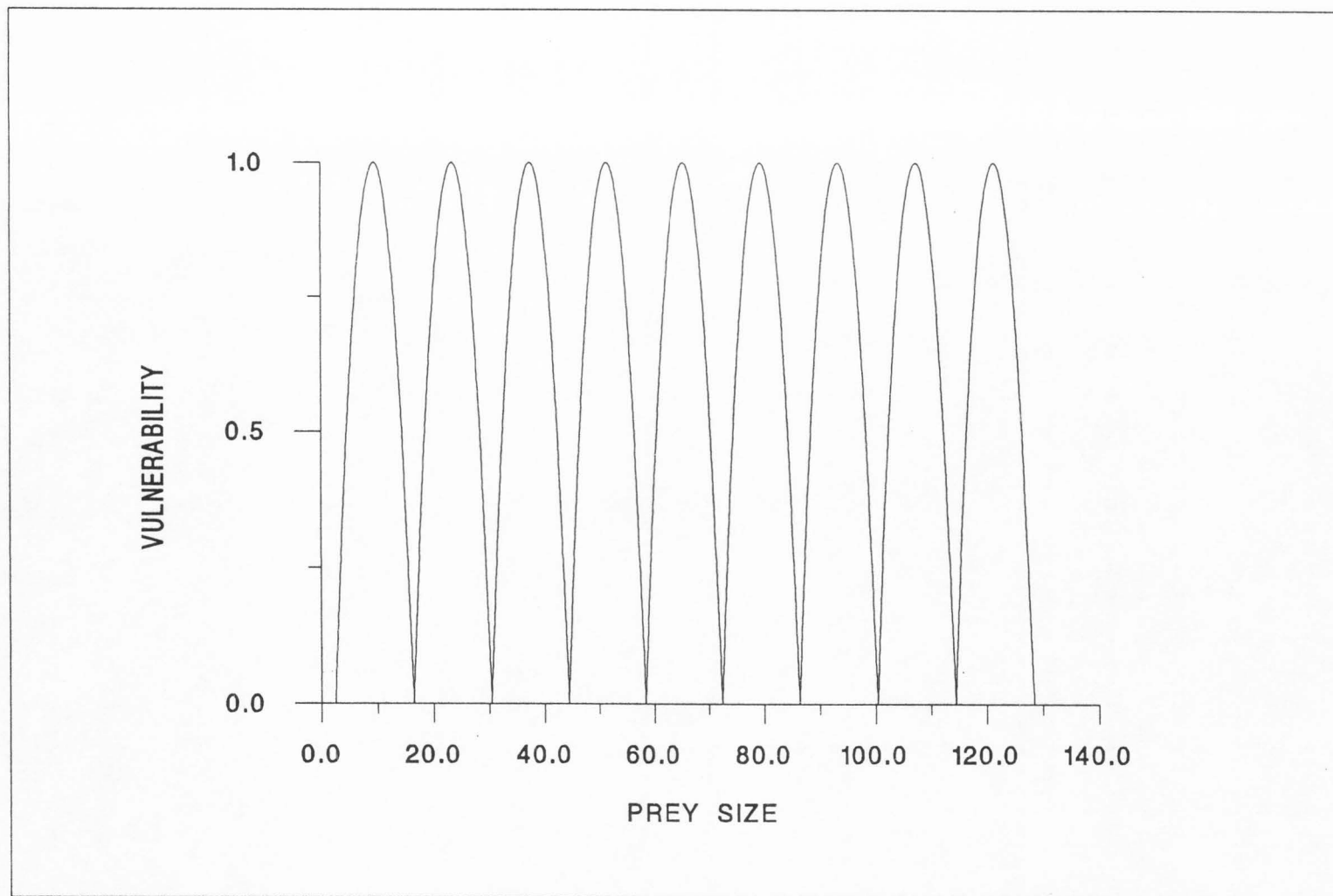


Fig. 2

Fig. 2

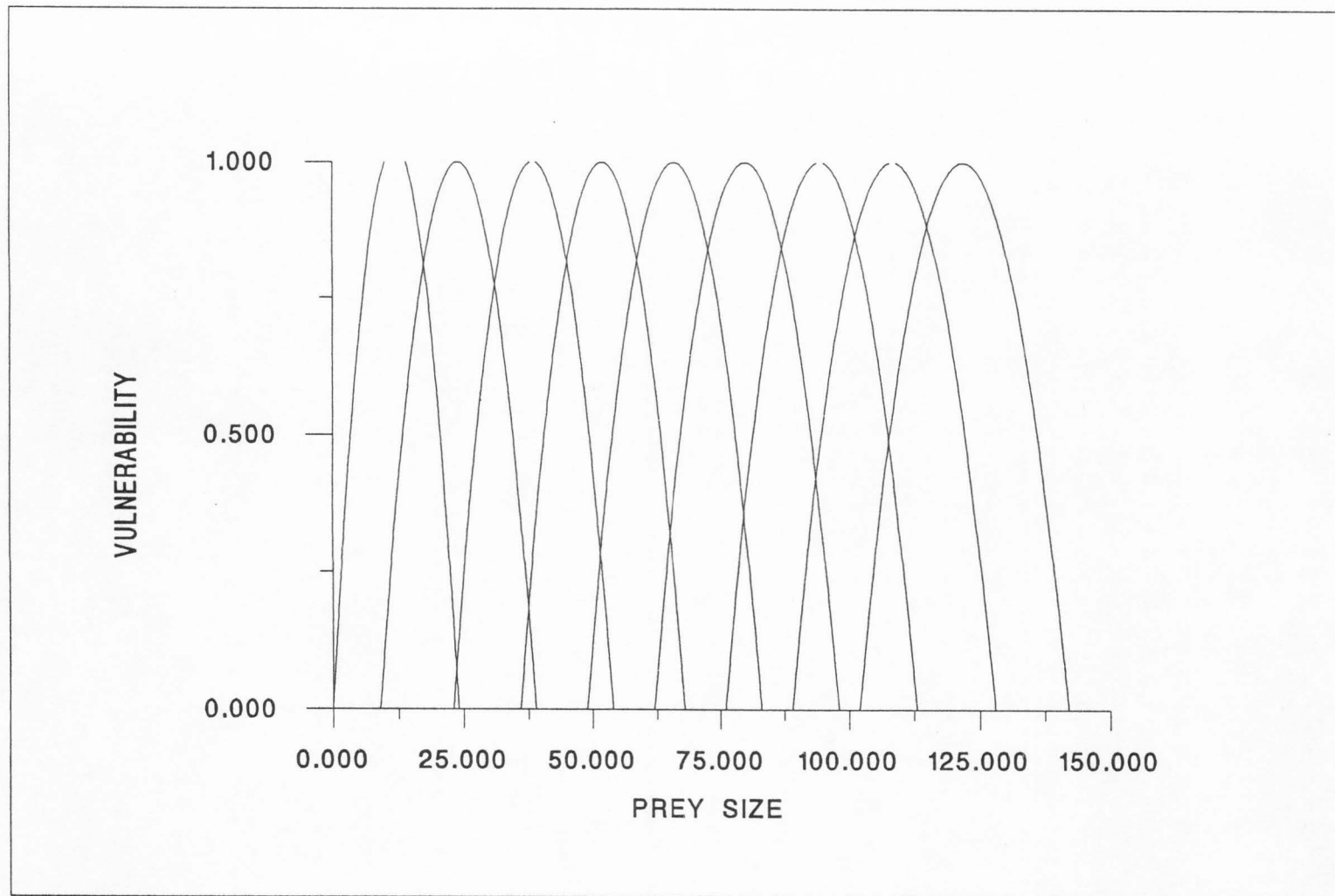


Fig. 3

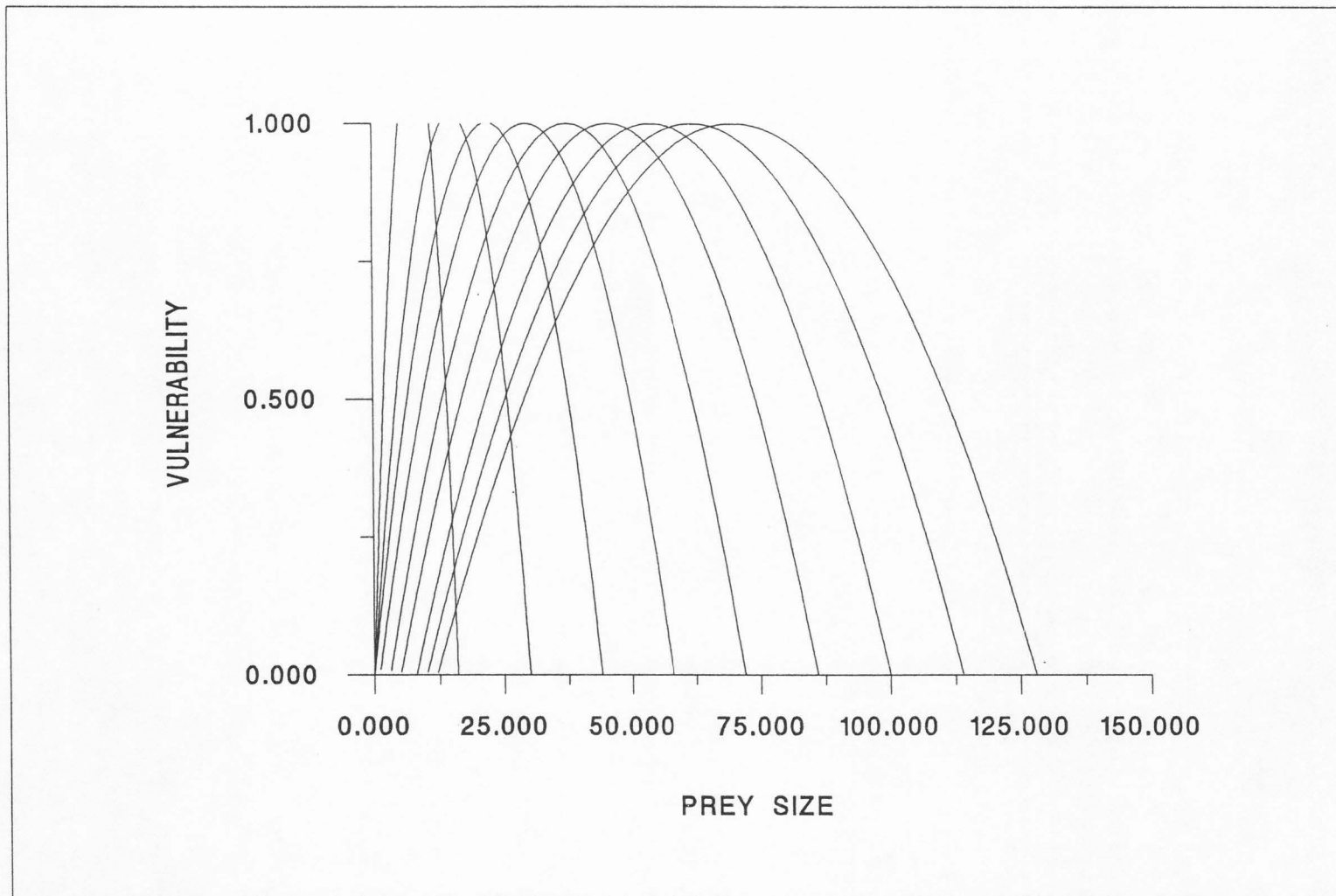
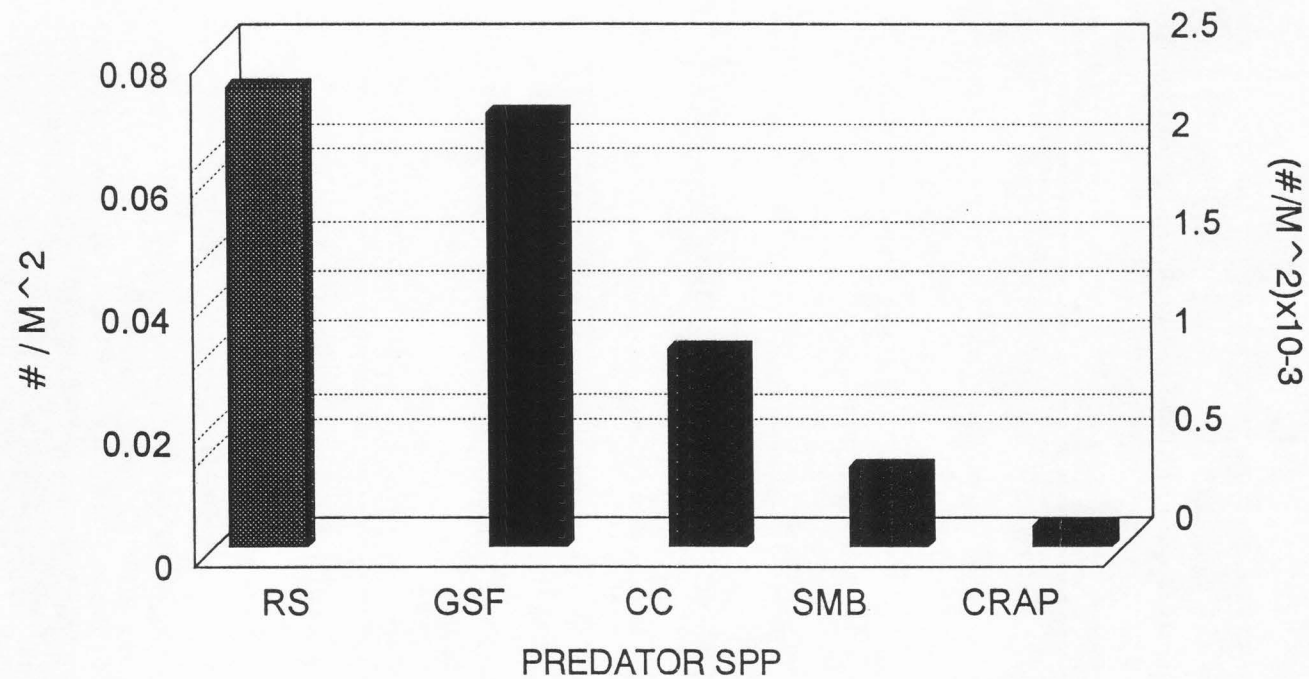


Fig. 4

PREDATOR DENSITY

OURAY 1994



RELATIVE ABUNDANCE OF PREDATORS BY 50-MM SIZE CLASSES

